VACUUM CONCRETE

The VACUUM CONCRETE PROCESS

Increases Strength
Improves Density
Reduces Absorption

BY REMOVING EXCESS MIXING
WATER AFTER CONCRETE IS PLACED

VACUUM CONCRETE CORPORATION

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FOREWORD

Twenty years ago Prof. Duff A. Abrams, head of the Structural Materials Research Laboratory of the Lewis Institute, Chicago, Ill., formulated for the first time what is now known as the "water-cement ratio" law.

This law, based originally on a hundred thousand tests, and since proved and accepted by engineers all over the globe as basic and fundamental in concrete-making, may be stated roughly as follows:

> In a plastic and workable concrete (made with sound and clean materials) the strength and other desirable properties <u>are governed by the net quantity of mixing water used per sack of cement</u> (the water-cement ratio.)

In a word, as the amount of mixing water is reduced, the strength of the concrete increases. For example:

7	gals.	per	sack	3,000	lbs.	sq. in.
6	"	"	"	4,000	"	"
5	"	"	"	5,000	"	"

From this table, it will be seen that a 66% increase in strength is obtained <u>solely by reducing the amount of mixing water.</u>

There has, however, been one important barrier to keep engineers from making the fullest use of this knowledge. As the amount of mixing water is decreased the concrete becomes less plastic or workable, and is therefore more difficult - and so more costly - to handle and place.

Now, with the advent of the VACUUM CONCRETE PROCESS, a revolutionary change is effected, and for the first time it becomes possible to obtain the high strengths and other advantages associated with "dry" concretes, while retaining the speed of placing and economy of the wetter mixes.

THE VACUUM CONCRETE PROCESS

Briefly, the VACUUM CONCRETE PROCESS is a method of removing from concrete, after it has been placed in the forms, the excess mixing water - the water which is added to make the concrete "workable," but which is not needed to hydrate (or "set") the cement.

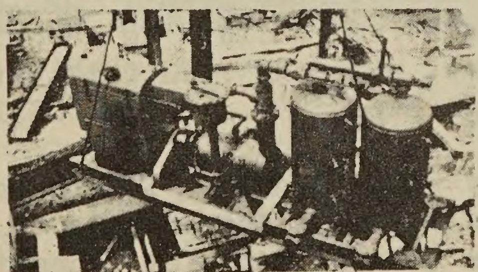
At the same time, the concrete which is being processed is subjected to a compacting action due to an atmospheric pressure of about 1500 lbs. per square foot, which results from the high vacuum employed. This produces a dense concrete of "no-slump" consistency which, however, still retains ample water to enable the cement to set properly.

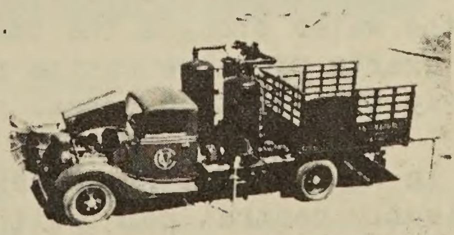
The VACUUM CONCRETE PROCESS thus realizes the aim of engineers and concrete technicians for two decades - concrete which is wet enough for economy in handling and placing, but which at the same time makes it possible to achieve the high strength and other desirable qualities which go with a low water content, in accordance with the water-cement ratio law.

The desirable qualities possessed by concrete of minimum mixing water content are noted below. Evidences of the beneficial effect of the VACUUM CONCRETE PROCESS on many of these points are given on subsequent pages.

High Early Strength
Increased Ultimate Strength
Lowered Absorption
Increased Bond Strength
Greater Resistance to Freezing and Thawing
Less Wear
Reduced Shrinkage

Various applications of the VACUUM CONCRETE PROCESS are described hereafter.





Vacuum Concrete pump and tank assemblies.

OPERATION OF VACUUM CONCRETE PROCESS

As an aid to understanding the process, it may be stated that the unwanted water in the mix - the water which is added solely to make the concrete workable - is withdrawn by means of suction mats connected to a vacuum pump. The mats may be part of the forms, or in treating horizontal surfaces, the mats may be loose and applied on top of the concrete after the slab has been leveled off.

Various types of mats are used, but essentially a mat consists of a tight backing of some kind - wood, metal, or rubber - having on the surface next the concrete passageways through which the extracted water can flow to a suction outlet. Where rubber mats are employed, a knobbed surface is therefore selected; with wood or metal mats or forms the necessary waterways are obtained by attaching light expanded metal lath to the face of the panels. The waterways are in all cases covered with a filter fabric, against which the concrete is cast. A band of plain rubber around the edge of the mat is always necessary to form a seal against loss of vacuum.

In the case of a wall, the VACUUM CONCRETE process makes it possible to use much lighter forms than would otherwise be considered, and at the same time do away with most of the tie wires, bolts, walers, braces, etc. which with the finishing constitute such an important part of the cost of the finished wall.

For example, in addition to the edge seals on each form panel mentioned above, additional seals can be used so that a form panel 4 ft. wide and 10 ft. high might, by the use of horizontal seals every two feet, be divided in effect into a series of independent mats each 2 x 4 ft. By so arranging the seals, it is possible, as the form is filled with concrete, to apply suction as soon as the concrete has reached the first seal, 2 ft. above the bottom of the form, instead of waiting until the entire 10 ft. of concrete has been cast; in like manner suction can be successively applied as each additional 2 ft. of concrete is placed in the forms. As the removal of the water changes the concrete from a fluid to a solid, it no longer exerts pressure on the forms, with the result that the forms have only to withstand a head of perhaps 3 ft. instead of 10 ft.

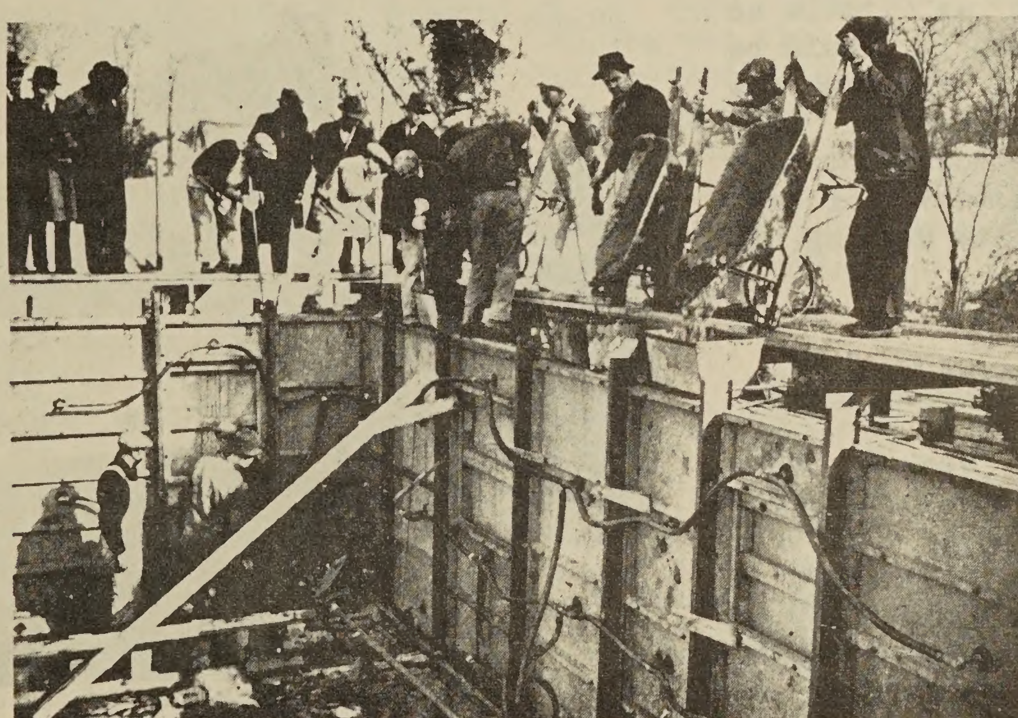
In operation, the necessary vacuum pump is located at some conveniently central point with relation to the work to be done, and connected to one or more manifolds (multiple outlet connections) by means of a main suction line of light steel tubing. Instead of flanges, gaskets and bolts, the individual lengths of steel tubing are equipped with flexible rubber cups which are self-sealing one to the

other under vacuum. Each manifold provides connections for several lines of rubber hose leading to the forms. At the far end of each hose line is a soft rubber cup, somewhat similar to that used by plumbers for clearing clogged drains. A stopcock is located just back of the cup, and is opened or closed as required.

In order to attach the suction lines to the mats or forms, it is only necessary to place the cup over the suction outlet, and open the stopcock. The cup immediately seals itself tight to the form. An 8" wall, under suction from both sides, is hard enough in 30 minutes so that forms can be removed, and finishing started.

As there are no wires to cut or bolt holes to fill, finishing is simple and inexpensive. A float finish is obtained by lightly rubbing with a rubber sponge, or a skim coat of cement mortar may be applied.

As the concrete is still only a matter of minutes old, stucco bonds to and becomes part of the wall as it could never do otherwise.



DEPOSITING CONCRETE in wall forms equipped with vacuum cups to remove the excess water on a house near Washington, D. C.

Pouring of the first half of the house, begun about 11 a.m., was completed at 1 p.m., and the first form panel was removed by 2:15 p.m. The surface of the fresh concrete was hard and firm, with an even texture reproducing the details of the corrugated rubber seal strips and the mesh lining. A workman walked across the upper exposed edge of the fresh slab without causing any perceptible flaking or chipping.

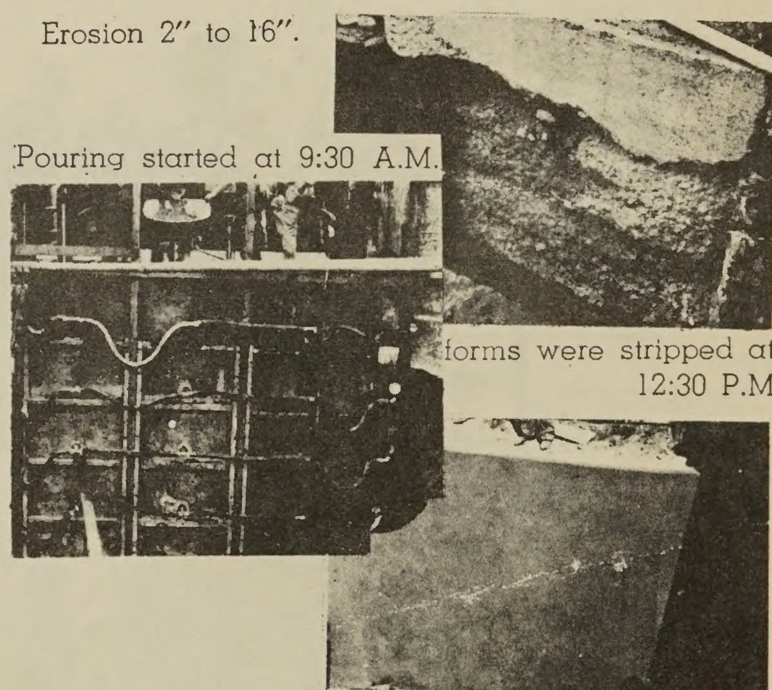
At 2:45 p.m. masons started to apply a $\frac{1}{8}$-in. surface coat, made up of one part white cement and two parts of white sand, to the exterior of the walls. Although the walls at that time were hard, final set of the cement had not occurred, so that it is claimed surface and wall are truly monolithic.

APPLICATIONS AND ADVANTAGES OF THE VACUUM CONCRETE PROCESS

Below are listed a few of the many applications of the process, with a brief mention of the advantages which inhere in its use for that particular purpose.

WALL CONSTRUCTION.

One sided Walls (Walls cast against rock, existing structures, etc.) Usually difficult and expensive to form because unbalanced pressure of concrete makes elaborate horizontal or spur-bracing necessary. With VACUUM CONCRETE it is possible to use forms, as described on page 4, in which pressure of concrete is continuously relieved by Vacuum treating as forms are filled. Bursting pressure may thus be reduced to as little as 5% of what it would be otherwise; if forms are securely held in line and position, top and bottom little, if any, intermediate bracing is required.


Erosion 2″ to 16″.
Pouring started at 9:30 A.M.
forms were stripped at 12:30 P.M.
Job complete in one day.

HOLLOW RESIDENCE WALLS.

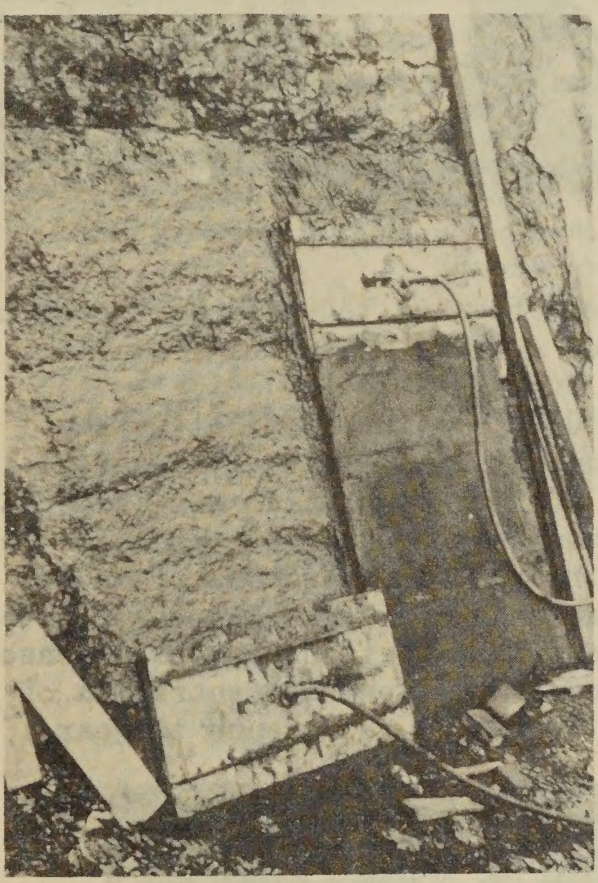
Use of method of form construction mentioned on page 4 so relieves the strains on the forms that where a plane surface is not essential building paper can be used for forms.

For the house at Bethesda, Md., shown under construction on page 5, hollow walls were provided by first setting up on the center line of the wall, light wooden studs over which was nailed 8' wide Sisalkraft paper, to form air space in center of wall. Forms for outer faces of wall were then erected, leaving 3" between the Sisalkraft paper and outer forms. The walls for this 27' x 35' residence were cast, Vacuum processed, forms removed and 1/8" skim coat of white cement stucco applied, all in one day, under winter conditions. Finished wall consisted of two 3" reinforced concrete shells with 3" air space between.

"SKYHOOK FORMS"

This is a term which has been applied to certain types of unit VACUUM CONCRETE forms in which major reliance is placed upon atmospheric pressure, (resulting from the high vacuum used), to hold the forms in place on the wall. These forms have been used with conspicuous success for construction of free-standing walls (House at Rye, N.Y.) and one-sided walls (Bridge Abutment, Providence, R.I., repair patch on weathered down stream face of dam), etc.

In principle, form which has just been concreted and which is under atmospheric pressure from vacuum suction, holds itself in place so firmly that it can be used as support for the next form above. The walls of the Rye house were built in a continuous hand-over-hand operation with a pair of 15" high forms, 10' long, topping out the walls in one day. This method is especially adapted for applying new facings to existing structures, because of economy and simplicity of forms and avoidance of costly drilling and anchor bolting or bracing to hold forms in place.



"Sky-hook" VACUUM CONCRETE Forms refacing weathered concrete dam.

HIGHWAY RESURFACING

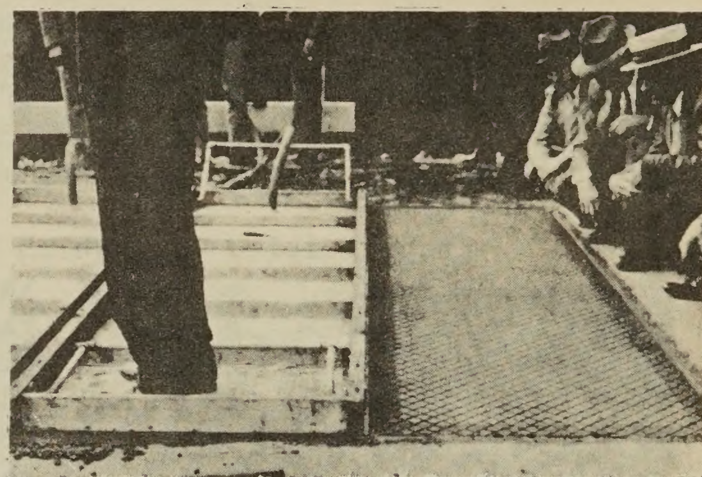
Because of difficulty of obtaining a perfect bond between new surfacing and old pavement, it has been customary heretofore to make concrete resurfacing not less than 4" thick.

The high atmospheric pressure on VACUUM CONCRETE suction mats (approximately 1500 lbs. per sq. ft.) develops a bond between a VACUUM CONCRETE resurfacing and the old pavement slab which makes it possible to reduce the thickness of the concrete resurfacing to 2".

Test installations have been made in Rhode Island and New York. These installations which have been down on heavily traveled

roads for more than 1½ years show no sign of loosening of bond between the base and the 2" VACUUM CONCRETE topping.

BRIDGE DECKS

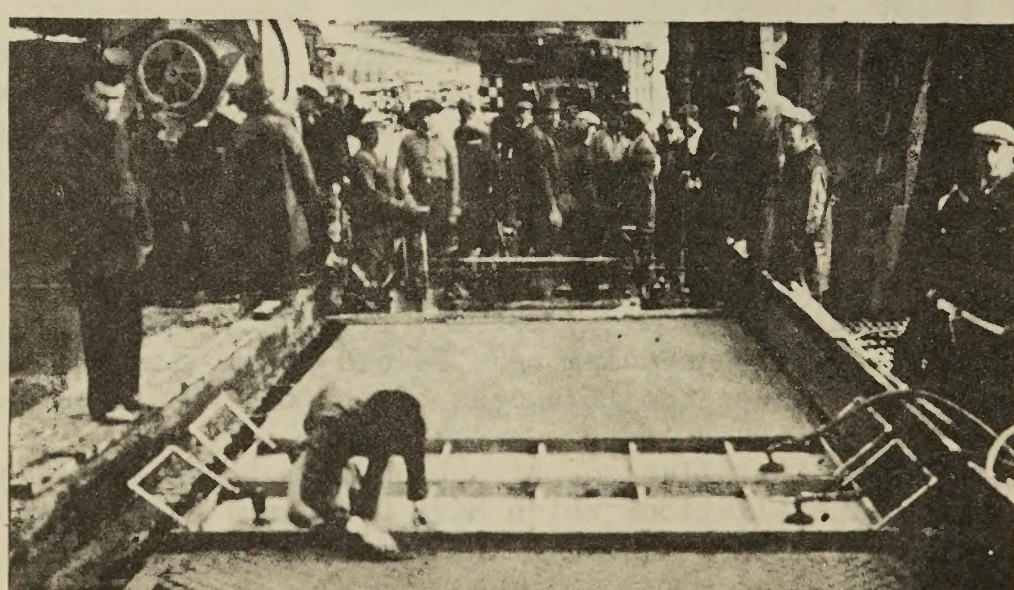


2" Non-skid Vacuum Concrete resurface on concrete road.

Durability and resistance to wear are of paramount importance on bridge decks. Traffic tends to flow in definite lanes far more than on the open road, resulting in a concentration of wear.

A VACUUM CONCRETE bridge deck possesses unusual resistance to wear. Even where a relatively dry mix is used and vibrated into place, the process can be used to withdraw excess mixing water and compact the concrete.

The VACUUM CONCRETE PROCESS has two distinct safety angles which are particularly important on elevated structures: (1) Vacuum mats can be so designed as to impress special non-skid patterns on the surface of the concrete, which could not otherwise be obtained; and (2) as a result of the superior hardness of VACUUM CONCRETE, such non-skid surface markings will maintain their integrity for a much longer period. (Test installations on the Queensborough Bridge, which is reputed to carry heaviest concentration of motor traffic in the world, shows excellent resistance to wear.)



Vacuum Concrete on Queensboro Bridge

TYPICAL COMPRESSION TESTS:

High Early Strength Cement

6" x 6" Cylinders. High Early Strength Cement, L.I. Sand and 3/4" Gravel.
Mix: 1:1½: 3 Plain and Vacuum Concrete.
Slump: 2 inches.

Age at Test - 20 hours.

Plain Concrete	Vacuum Concrete
3270	4740
2970	4690
Average 3120 lbs. per sq. in.	Average 4715 lbs. per sq. in.

Increase in Strength due to Vacuum Treatment -- 51.5%

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5.62 inch Cylinder Cores, 8.25 inches high.
High Early Strength Cement, L.I. Sand and 3/4" Broken Stone.
Mix: 1:1¾:3½ Plain and Vacuum Concrete.
Slump: 2 inches.

Age at Test - 4 days.

Plain Concrete	Vacuum Concrete
4580	6150
4355	5960
4437	5902
Average 4457 lbs. per sq. in.	Average 6004 lbs. per sq. in.

Increase in Strength due to Vacuum Treatment -- 34.7%

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6" x 6" Cylinders, High Early Strength Cement, Sand and 3/4" Gravel.
Mix: 1:3:6 Plain and Vacuum Concrete
Slump: 6½ inches

Age at Test - 3 days.

Plain Concrete	Vacuum Concrete
1412	2449
1388	1794
1067	2145
Average 1289 lbs. per sq. in.	Average 2129 lbs. per sq. in.

Increase in Strength due to Vacuum Treatment -- 64%

COMPRESSION TESTS (Cont'd) - Lean Mixes

6" x 6" Cylinders, Standard Portland Cement, Sand and 3/4" Gravel.
Mix: 1:3:6 Plain and Vacuum Concrete
Slump: 6½ inches.

Age at Test - 7 days -

	Plain Concrete	Vacuum Concrete
	2020	2750
	2080	2800
Average:	2050 lbs. per sq. in.	2775 lbs. per sq. in.

Increase in Strength due to Vacuum Treatment - 35.5%

Age at Test - 28 days -

	Plain Concrete	Vacuum Concrete
	2460	3420
	2280	3500
Average:	2370 lbs. per sq. in.	3460 lbs. per sq. in.

Increase in Strength due to Vacuum Treatment - 46%

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6" x 6" Cylinders, Standard Portland Cement, Sand and 3/4" Gravel.
Mix 1:4:8 Plain and Vacuum Concrete
Slump: 2 inches.

Age at Test - 7 days -

	Plain Concrete	Vacuum Concrete
	592	1210
	620	1315
Average:	603 lbs. per sq. in.	1262 lbs. per sq. in.

Increase in Strength due to Vacuum Treatment - 110%

Age at Test - 28 days -

	Plain Concrete	Vacuum Concrete
	1030	1850
	1210	1780
Average:	1120 lbs. per sq. in.	1815 lbs. per sq. in.

Increase in Strength due to Vacuum Treatment - 62%

6" x 6" Cylinders, Standard Portland Cement, Fine and coarse Haydite aggregate.
Mix: 1:2:3½ Plain and Vacuum Treated.
Slump: 6 inches

Age at Test - 3 days -

Plain Concrete	Vacuum Concrete
1334	2080
1161	1772
1209	2168
Average: 1234 lbs. per sq. in.	2007 lbs. per sq. in.

Increase in Strength due to Vacuum Treatment - 63%

Age at Test - 28 days -

Plain Concrete	Vacuum Concrete
2966	3804
2747	4476
2768	4029
Average: 2827 lbs. per sq. in.	4103 lbs. per sq. in.

Increase in Strength due to Vacuum Treatment - 45%

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6" x 6" Cylinders, High Early Strength Cement, Sand and Cinders.
Mix: 1:2:4 Plain and Vacuum Concrete.
Slump: 6 inches.

Age at Test - 24 hours -

Plain Concrete	Vacuum Concrete
267	535
294	555
Average: 280 lbs. per sq. in.	545 lbs. per sq. in.

Increase in Strength due to Vacuum Treatment - 94%

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6" x 6" Cylinders, High Early Strength Cement, Sand and Cinders.
Mix: 1:2:5 Plain and Vacuum Concrete.
Slump: 3 inches.

Age at Test - 3 days -

Plain Concrete	Vacuum Concrete
702	1095
634	900
Average: 668 lbs. per sq. in.	997 lbs. per sq. in.

Increase in Strength due to Vacuum Treatment - 49%

ABSORPTION

4" cubes, Lone Star Cement, L. I. Sand and broken stone

Mix: Plain Concrete 1:2½:5
Vacuum Concrete 1:3 :6

Slump 4"
Samples placed in boiling water 3 hours and weighed wet; then dried to constant weight and weighed dry.
Absorption as given is percentage of dry weight.

	Plain Concrete		Dry Concrete
	6.08%		4.58%
	5.47		4.11
Average	5.78%	Average	4.35%

Percentage less absorption due to Vacuum Treatment - 25%

From tests made by Cast Stone Institute on Cast Stone mixes:

Mix 1:3½ Water as noted

Plain Cast Stone	7.6%
Same, Vacuum Processed	5.6
	2.0%

Percentage less absorption due to Vacuum Treatment - 26%

Plain Cast Stone (Vibrated)	5.7%
Same, Vacuum Processed	4.9
	.8%

Percentage less absorption due to Vacuum Treatment
of low slump, Vibrated mix - - - - - - - - - - - - - 14%

BOND TESTS

6" Cubes - 1-2-4 Mix 3/4" bar embedded 6".

ORDINARY PORTLAND CEMENT Age at test - 3 days -

Max. Load Plain Conc.	Bond Strength Lbs./Sq.in.	Max. Load Vacuum Conc.	Bond Strength Lbs./ Sq.in.
3120	220	5620	397
2710	192	4320	306
Average	206	Average	357

Increase in Strength due to Vacuum Treatment -- 70.5%

ORDINARY PORTLAND CEMENT Age at test - 32 days -

Max. Load Plain Conc.	Bond Strength Lbs./Sq.in.	Max. Load Vacuum Conc.	Bond Strength Lbs./Sq.in.
4300	318	10200	721
3800	269	5300	375
Average	294	Average	548

Increase in Strength due to Vacuum Treatment -- 86.5%

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HIGH EARLY STRENGTH CEMENT - Age at Test - 3 days -

Max. Load Plain Conc.	Bond Strength Lbs./Sq.in.	Max. Load Vacuum Conc.	Bond Strength Lbs./Sq.in.
3570	252	6410	453
3220	228	5110	362
2310	163	4820	341
Average	215	Average	385

Increase in Strength due to Vacuum Treatment -- 79.5%

HIGH EARLY STRENGTH CEMENT - Age at Test - 32 days -

Max. Load Plain Conc.	Bond Strength Lbs./Sq.in.	Max. Load Vacuum Conc.	Bond Strength Lbs./Sq.in.
5400	382	10500	743
4800	339	7650	541
4800	339	6750	478
Average	353	Average	587

Increase in Strength due to Vacuum Treatment -- 66.3%

TRANSVERSE BENDING

Three sets of tests have been made at various times. The first test was on 6" by 6" unreinforced beams 1:2:4 mix High Early Strength Cement, slump $5\frac{1}{2}$". Beams were broken at 3 days with the following results:

Plain concrete: 290 lbs. per sq. in. tension

Vacuum Concrete: 424 " " " " "

Average increase in Stress in Vacuum-processed Specimens - 46%

A second set of tests was subsequently run on reinforced concrete beams of 1:2:4 mix, ordinary cement, 4" slump. Both beams were over-reinforced and over-loaded to produce failure in concrete. The results were as follows:

	Plain Concrete	Vacuum Concrete
~~Steel Stress:~~	~~19000 lbs. per sq. in.~~	~~3130 lbs. per sq. in.~~
Concrete:	1160 " " " "	2120 " " " "

Average increase in Stress due to Vacuum Processing - 82%

A third set of tests was made on over-reinforced slabs, approximately 4 ft. 1" by 5 ft. 5% by 6" topping. Mix: 1: $1\frac{1}{2}$:3 ordinary portland cement, slump 5".

	Plain Concrete	Vacuum Concrete
First cracking:	30,000 lbs.	55,000 lbs.
Additional cracking:	45,000	70,000
Failure	85,800	97,000

REDUCED SHRINKAGE

Shrinkage in concrete after setting is a troublesome characteristic which heretofore it has been difficult to control. This shrinkage is a cause of cracking, surface checking, and crazing, leakage, frost damage, etc.

Shrinkage is traceable to two factors - (1) original water content of concrete and (2) richness of mix (cement content) in the order of their importance. Wet mixes shrink more in drying than do dry mixes; rich mixes shrink more than lean.

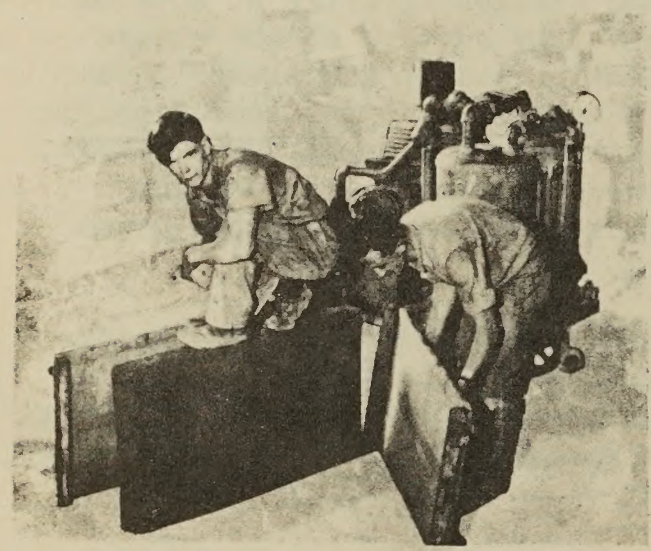
The VACUUM COMPRESSION PROCESS strikes directly at both of these causes of shrinkage. The removal by suction of the excess mixing water results in the equivalent of a dry, "no slump" concrete whose shrinkage is reduced to a minimum. At the same time, it is possible in many cases to use leaner mixes with VACUUM CONCRETE, because of the greatly increased strength which follows Vacuum processing. These leaner mixes shrink less than the richer mixes which would otherwise be used.

Tests on unprocessed cast stone showed a drying-out shrinkage of .65 inches per 100 ft. Under the same conditions, vibrated dry mixes showed a shrinkage of approximately .52 inches per 100 ft. Vacuum-processed specimens showed a shrinkage of only .45 inches per 100 ft.

A practical example of this highly desirable characteristic of Vacuum Concrete is to be found in a demonstration slab laid more than a year and a half ago on a heavily traveled bridge deck. Although this slab is 66 feet long there is no sign of shrinkage cracking, while very fine shrinkage cracks have generally appeared in other slabs of lesser length on this same structure. The same concrete was used in all cases, and was of excellent quality. Workmanship and supervision was also above reproach. VACUUM CONCRETE simply makes even high grade concrete still better.

The two culvert sections shown in the photograph were cast, Vacuum processed and both inner and outer forms removed within 2 hours.

Vacuum treated sections of poured-in-place concrete culverts.



Ten minutes after Vacuum treatment. Forms removed. Wall section bearing weight of man.

Precast Concrete Piles:

Strength for a given mix increased 50%; forms removed 20 to 30 minutes. Less space required for casting and storage. Shrinkage cracking minimized. Handled and driven earlier with less danger of breakage.

The process has actually been used for the various applications mentioned, as well as many not given herein. Other uses will undoubtedly suggest themselves. We will be glad to discuss at any time construction features or problems where it might seem that the structure could be improved, the work expedited, or costs lowered by using the VACUUM CONCRETE PROCESS. No obligation is involved or implied and if the conditions are such that the process is not suitable we shall be frank to say so.

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